2.13 DETAILED RESULTS FOR MULTIPATH AND DIFFRACTION

Several discrepancies were found in the native mode implementation of multipath in ESAMS 2.6.2. These include calculating multipath effects when no multipath is possible (i.e., when the first Fresnel zone does not intersect the ground plane) and using an approximation instead of an exact calculation of the length of the first Fresnel zone. Other problems discovered were incorrect calculation of facet azimuth and elevation angles and an error in determining whether or not the last facet has been reached during the examination of the segments of the site-target ground line. In addition, small angle approximations are used without checks that the angles are small enough for these methods. No discrepancies were found in the GRACE mode implementation of multipath.

Code quality is acceptable, but some improvements are recommended. Internal documentation for native mode is very good in many respects, but some additions would be helpful. For GRACE mode, the header is not consistent with the code and there are too few internal comments. External documentation was not evaluated because the ESAMS 2.5 manuals were not updated for ESAMS 2.6.2.

Table 2.13-1 and 2.13-2 summarize the desk checking and software testing verification activities for each design element in the Multipath and Diffraction Functional Element. The two results columns contain checks if no discrepancies were found. Where discrepancies were found, the desk check results column contains references to discrepancies listed in Table 2.13-4 (native mode) or Table 2.13-5 (GRACE mode), while the test case results column lists the number of the relevant test case in Table 2.13-9 (native mode) or 2.13-10 (GRACE mode).

TABLE 2.13-1. Verification Results for Native Mode Multipath.

Design Element	Code Location	Desk Check Result	Test Case ID	Test Case Result
13-1: Grid Geometry Initialization	MULTIP 248-262 FACIN 114-170	√	13-21, 22, 23	√
13-2: Intercept Arrays	FACIN 175-203	√	13-24	√
13-3: Next Facet Segment	FACET 136-176	D1	13-17, 18, 19	13-18
13-4: Next Intercept	FACET 226-253	D2	13-20	√
13-5: Specular Geometry	MULTIP 263-264 330-417 427-460	√	13-1, 2, 3, 4	√
13-6: Diffuse Reflection Coefficient	MULTIP 479-538 641-674	√	13-5, 6, 7	√
13-7: Specular Reflection Coefficient	MULTIP 418-426 461-478 676-746	D3	13-8, 9	13-9
13-8: Multipath Signals	MLTRSP 142-151 162-202 236-261 277-283	D4	13-10, 11, 13, 14, 15, 16	13-11
13-9: Doppler Centroid	MLTRSP 154-159 208-222 264-269 285-291	√	13-12	√

TABLE 2.13-2. Verification Results for GRACE Mode Multipath.

Design Element	Code Location	Desk Check Result	Test Case ID	Test Case Result
13-10: Terrain and Geometry	GRCMLT 160-205 232-258	√	13-25, 26, 28, 29	√
13-11: Specular Reflection Pattern	GRCMLT 259-265	√	13-30	√
13-12: Multipath Voltage	GRCMLT 210-225 267-305 314-347 365-358	√	13-27, 31, 32, 34, 35, 36	√
13-13: Doppler Centroid	GRCMLT 308-312 350-355 370-373	√	13-33	√

2.13.1 Overview

In ESAMS 2.6.2, FE 2.3 models only the multipath interference effects. Diffraction effects are not addressed. Multipath is an interference condition that usually occurs at low tracking altitudes when reflected energy is received from round-trip paths other than direct reflection. The power and direction of return of multipath signals are determined by the radar range equation, path geometry, and scattering surface properties. Multipath effects are modeled using two separate implementation modes: the Native mode and the Ground Radar Clutter Estimator (GRACE) mode. The Native mode is based on the theoretical multipath propagation models developed by Barton and others. These models account for specular and diffuse scattering over rough, oriented surfaces representing terrain. The GRACE mode is based on multipath methodology developed at Lincoln Laboratories and incorporates site mask data derived from Defense Mapping Agency (DMA) digital terrain elevation data (DETED).

Seven subroutines implement the Native multipath model. The main computational routines for the multipath model are subroutines MULTIP and MLTRSP. These routines compute the multipath signal response. The initialization routines are MULTIN and FACIN which establish constants and terrain boundary conditions. Subroutines FACET, FSHAD and BSHAD are geometric in nature and determine the site-target relationship to the terrain data.

A single subroutine GRCMLT implements the whole of the computational design of GRACE multipath model and computes the sum and difference channel voltage signals due to specular and diffuse multipath reflection. GRACE uses Site Mask data which is a much condensed representation of the terrain-form data.

All subroutines used for this FE are described in Table 2.13-3.

TABLE 2.13-3. Subroutine Descriptions.

Module Name	Description
FACET	Determines the participating terrain facets for a given radar site and target position geometry. (Native mode)
FACIN	Loads and initializes facet data. (Native mode)
MULTIN	Initializes variables for multipath calculations. (Native mode)
MULTIP	Calculates the specular and diffuse multipath reflection coefficients. (Native mode)
MLTRSP	Calculates the sum and difference channel voltages due to multipath effects. (Native mode)
GRCMLT	Performs all multipath processing in GRACE mode; calculates sum and difference channel voltages due to multipath effects. (GRACE mode)

2.13.2 Verification Design Elements

The design elements defined for multipath are listed in Tables 2.13-4 and 5. A design element is a feature or algorithm that represents a specific component of the FE design. The multipath design elements are fully described in Section 2.13.2 of ASP-II for ESAMS.

TABLE 2.13-4. Native Mode Multipath Design Elements.

Subroutine	Design Element	Description
MULTIP	13-1: Grid Geometry Initialization	Convert standard parameters to grid units and find coordinates of last possible facet for multipath.
FACIN	13-2: Intercept Arrays	Compute x and y intercept increments and initial gridline intercept points for the ground line from radar site to target.
FACET	13-3: Next Facet Segment	Find length of ground line segment across the next facet.
FACET	13-4: Next Intercept	Find the next horizontal and vertical grid line intercepts of the ground line.
MULTIP	13-5: Specular Geometry	Determine whether or not a facet contributes a specular return.
MULTIP	13-6: Diffuse Reflection Coefficient	Compute diffuse reflection coefficient.
MULTIP	13-7: Specular Reflection Coefficient	Compute specular reflection coefficient.
MLTRSP	13-8: Multipath Signals	Compute sum and difference channel voltages due to multipath effects.
MLTRSP	13-9: Doppler Centroid	Compute apparent doppler shift of composite multipath signal (for use in MTI processing).

TABLE 2.13-5. GRACE Mode Multipath Design Elements.

Subroutine	Design Element	Description
GRCMLT	13-10: Terrain and Geometry	Select radial for Site Mask data and calculate effective facet length and effective scattering area.
GRCMLT	13-11: Specular Reflection Pattern	Compute power pattern for the reflection from the patch to the target.
GRCMLT	13-12: Multipath Voltage	Compute sum and difference channel voltages due to multipath effects.
GRCMLT	13-13: Doppler Centroid	Compute apparent doppler shift of multipath signal (for use in MTI processing).

2.13.3 Desk Check Activities and Results

The code implementing this FE was manually examined using the procedures described in Section 1.1 of this report. Any discrepancies discovered are described in the following table.

TABLE 2.13-6. Native Mode Code Discrepancies.

Design Element	Desk Check Result
13-3: Next Facet Segment	D1: The check to determine if the ground line has reached the last facet is in error. The conditional test will always be passed when sign (x) = sign (y) = 1 and will always fail when sign (x) ≠ sign (y).
13-4: Next Intercept	D2: The conditional statement that determines whether the next intersection of the ground line is with a vertical or horizontal grid line is in error. The "LE" should be replaced by "LT".
13-7: Specular Reflection Coefficient	D3: No check is made to ensure that angles are small enough to use small angle approximations.
13-8: Multipath Signals	D4: Computations of facet azimuth (TAX) and elevation (TEI) are incorrect because these angles are given in the boresight reference frame, not the radar site reference frame.

No code discrepancies were found during desk-checking of the GRACE mode multipath implementation.

Except as noted in Table 2.13-7 below, overall code quality and internal documentation were evaluated as good. Subroutine I/O and logical flow were found to match the ASP II descriptions.

TABLE 2.13-7. Code Quality and Internal Documentation Results.

Subroutine	Code Quality	Internal Documentation
MULTIP	OK	Some comments refer to numbered references, which are not identified in the code. There is no comment in the code to document the fact that the vegetation scattering coefficient is unity.
FACET	Mixed mode arithmetic at lines 156 and 157. The value of the variable INDX is used strictly locally, it should not be in common block SIMVI.	OK
GRCMLT	The variable ZTRI resulting from the random draw on line 284 is not used computationally. It is used only in conditional logic to determine if any return is present. This Ricean draw may be necessary.	The subroutine header is not consistent with the code and there is very little line-by-line documentation during the geometric calculations.

2.13.4 Software Test Cases and Results

Software testing was performed primarily by running the entire ESAMS model in debug mode to examine the subroutines in this FE. Unless otherwise indicated, the standard ESAMS data files for the systems under consideration were used as input for all test cases.

2.13.4.1 Native Mode Tests

Software tests 13-1 through 13-16 for Subroutines MULTIP and MLTRSP were performed using the following site-target positions:

Site: (125.0, 125.0, 3.0)
Target: (2625.0, 1625.0, 60.0)

Geometric calculations were compared to pre-calculated values for accuracy. Calls to subroutines that perform functions outside of the multipath functional element were executed and the output was examined for reasonable accuracy. It should be noted that some pre-calculated values do not necessarily match ESAMS values exactly due to round-off and approximation.

The lines of code that implement the radar range equation were executed and examined for reasonable output (direction, magnitude), but were not checked for accuracy since they heavily depend on antenna gain computations performed outside the multipath functional element. The coded implementations of these equations were examined during the desk checking stage and found to be correctly implemented.

Since there are relatively few input and output quantities associated with the facet geometry routines, Subroutines FACET and FACIN were executed off-line using a personal computer (Tests 13-17 through 13-24). This allowed efficient testing over several site and target locations. Computational tests were run on eight different site and target locations. Unless otherwise stated in Table 2.13-8 below, the radar site was located at:

(XSF, YSF, ZSF) = (2230.0, 2305.0, 3.0) and the targets (XT, YT, ZT), were positioned at:

a. (4155.0, 2305.0, 60.0)
b. (4225.0, 3760.0, 60.0)
c. (2230.0, 4195.0, 60.0)
d. (760.0, 3740.0, 60.0)
e. (805.0, 2305.0, 60.0)
f. (360.0, 725.0, 60.0)
g. (2230.0, 755.0, 60.0)
h. (4255.0, 205.0, 60.0)

These positions were chosen to exercise facet computations in all four quadrants and along all four axes.

Lines of code exist in subroutine FACET that compute transverse and horizontal facet tilt and the height of the facet edge at the groundline-gridline intersections. Since the facet tilt operations have been disabled in ESAMS 2.6.2, all facet tilts and edge heights will be zero. This was confirmed at the desk checking stage and no software tests were designed to exercise these lines of code.

TABLE 2.13-8. Native Mode Multipath Test Cases.

Test Case ID	Test Case Description
13-1	OBJECTIVE: Check line-of-sight distance from site to target: PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 249. 3. Examine variables XSJ, YSJ, ZSJ, XT, YT and ZT. Compare with pre-calculated values. 4. Stop on line 274. 5. Examine variable RLOSST and compare to pre-calculated value. VERIFY: ESAMS values match independent calculations in steps 3 and 4. RESULT: OK
13-2	OBJECTIVE: Check line-of-sight ranges from site to the facet and from the facet to the target. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 362. 3. Examine variables RLOSSF and RLOSFT. Compare with pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-3	OBJECTIVE: Check grazing angle calculations. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 412. 3. Examine variables PSI1 and PSI2. Compare with pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Independent calculations used exact methods while ESAMS uses small angle approximations. Results were comparable but not an exact match.
13-4	OBJECTIVE: Check bisector and relative grazing angle computations. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 476. 3. Examine variables BETAM, BETAA and BETAB. Compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Independent calculations used exact methods while ESAMS uses small angle approximations. Results were comparable but not an exact match.
13-5	OBJECTIVE: Check RMS scattering coefficient. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 515. 3. Examine variables RHOS1 and RHOS2. Compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Independent calculations used exact methods while ESAMS uses small angle approximations. Results were comparable but not an exact match.
13-6	OBJECTIVE: Check Fresnel coefficient calculation. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 544. 3. Examine variable PLR. 4. If PLR < 0.5 then examine variable RHOPV. 5. If PLR > 0.5 then examine variable RHOPH. 6. Compare to pre-calculated value. 7. Repeat steps 2-6 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Independent calculations used exact methods while ESAMS uses small angle approximations. Results were comparable but not an exact match.

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-7	OBJECTIVE: Check diffuse reflection coefficient. PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 674. 3. Examine variable PLR. 4. If PLR < 0.5 then examine variable RHODV. 5. If PLR > 0.5 then examine variable RHODH. 6. Compare to pre-calculated value. 7. Repeat steps 2-6 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-8	OBJECTIVE: Check specular logic and reflection coefficient calculation: PROCEDURE: 1. Stop in subroutine MULTIP. 2. Stop on line 700. 3. Examine variable POS(2,I) and compare to pre-calculated value. 4. If SPEC = TRUE then examine variable RHOM(I) and compare to pre-calculated value. 5. Repeat steps 2-4 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Values matched in Step 3. Values in Step 4 matched if ESAMS approximations were used for Fresnel zone lengths. (See test 13-9).

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

<table>
<tr><th>Test Case ID</th><th>Test Case Description</th></tr>
<tr><td>13-9</td><td>
OBJECTIVE: Check accuracy of approximation used in MULTIP for Fresnel zone length.
PROCEDURE:
This test was performed off-line (not by running ESAMS) since parameter values depend only on wavelength and site-target geometry.
1. Use the following values for height of radar sight (h_r), height of target (h_t) and horizontal ground range (G) from site to target.
hr   ht   G
3.0   60.0   40,000
35,000
30,000
25,000
20,000
15,000
10,000
2. Use Equation [2.13-39] from ASP II to calculate the approximate length (l) of the Fresnel zone for each value of G in step 1.
3. Compute the exact length, (L) of the Fresnel zone for each value of G in step 1, using the following formula:
$$x_M = \frac{h_t - h_r}{G}$$
$$a = \frac{(2R+\lambda)^2}{16},\quad b = \frac{\lambda^2 + 4\lambda R}{16},\quad c = \frac{G(h_t + h_r)}{2R}$$
$$A = \frac{b + a x_M^2}{ab},\quad B = \frac{2x_M c}{b},\quad C = \frac{c^2}{b} - 1,\quad D = B^2 - 4AC$$
$$L_i = \begin{bmatrix} \dfrac{R\sqrt{D}}{GA} & \text{if} \quad D \geq 0 \\ 0 & \text{if} \quad D < 0 \end{bmatrix}$$
where G is the total length of the ground line segment connecting the site and target and R is the line-of-sight distance between the site and target.
4. Compare the values calculated in steps 2 and 3.
VERIFY:
RESULT: The Fresnel zone length values that were calculated using the equations in step 3 above differed by as much as 2000 meters from those calculated by step 2. The impact on model performance is unknown at this time; however, the code correctly implemented the equations specified in the CMS. Also, note that a Fresnel zone length, was computed in the code for elevation angles that prevented the first Fresnel zone from intersecting the ground plane; thus, multipath effects were computed when no multipath was possible.
</td></tr>
</table>

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-10	OBJECTIVE: Check the target-site coordinate calculations and the target unit vector. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 175. 3. Examine variables XTS, YTS, ZTS, XTHAT, YTHAT, and ZTHAT. 4. Compare to pre-calculated values. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-11	OBJECTIVE: Check facet azimuth and elevation angles and the facet-to-target vector. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 218. 3. Examine variables XHAT, YHAT, ZHAT, XFACET, YFACET, ZFACET. 4. Compare to pre-calculated values. 5. Repeat steps 2-4 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-12	OBJECTIVE: Check doppler calculations. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 225. 3. Examine variable DOPPLR. 4. Compare to pre-calculated values. 5. Repeat steps 2-4 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-13	OBJECTIVE: Check composite multipath draws. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 205. 3. Examine variables RHOD, RHOM, and ZTRI. 4. Check ZTRI for reasonableness. 5. Repeat steps 2-4 for all facets. VERIFY: Values of ZTRI are reasonable. RESULT: OK

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-14	OBJECTIVE: Check antenna responses in the direction of the target and the facet. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 184. 3. Examine variable TSUM. 4. Stop on line 245. 5. Examine variables FSUM, DIF1 and DIF2. 6. Repeat steps 4 and 5 for all facets. VERIFY: Values of TSUM, FSUM, DIF1 and DIF2 are reasonable. RESULT: OK. The sum and difference channel signals TSUM, FSUM, DIF1 and DIF2 were examined for reasonable output. The value of TSUM was found to be -21.03200. FSUM ranged from about -0.46 to -0.55. DIF1 ranged from about 2.86 to 2.96 and DIF2 ranged from about -0.10 to -0.12. All values appear to be within range for reasonable operation.
13-15	OBJECTIVE: Check target aspect and signature. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 236. 3. Examine variables AZTGT, ELTGT, and FSIG for reasonable output. 4. Repeat steps 2 and 3 for all facets. VERIFY: Values of AZTGT, ELTGT, and FSIG are reasonable. RESULT: OK. The table look-up results for target aspect angles were examined for reasonable results. The progression of azimuth and elevation angles was found to be representative of the target aspect over the number of facets that were considered. The target radar cross section FSIGD also produced reasonable output.
13-16	OBJECTIVE: Check radar range equation calculations. PROCEDURE: 1. Stop in subroutine MLTRSP. 2. Stop on line 275. 3. Examine variables SUML1, DF1ML, DF2ML, DOPCNT and DENOM for reasonable output 4. Repeat steps 2 and 3 for all facets. VERIFY: The sum and difference channel signals examined were found to be reasonable. RESULT: OK

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-17	OBJECTIVE: Check whether the next groundline-gridline intersection occurs at a vertical or horizontal gridline. PROCEDURE: 1. Stop in subroutine FACET. 2. Stop on line 153. 3. Examine variable INDX and the products SYNEX*POINT(1,1) and SYNEY*POINT(2,1). 4. Compare to the pre-calculated values. 5. Repeat steps 1-4 for all test cases listed before this table. VERIFY: ESAMS results match independent calculations. RESULT: OK
13-18	OBJECTIVE: Check determination of grid coordinates of the current facet and the conditional that determines if the target (end point) has been reached. Confirm error found in desk checking. PROCEDURE: 1. Stop in subroutine FACET. 2. Stop on line 171. 3. Examine variables M, N, LPT, and KPT. 4. Compare M and N to the precalculated values of M_1 and N_1 (initial pass). 5. If M ≥ LPT and N ≥ KPT then note under C_1 that the conditional 6. passed, else note under C_1 that the conditional failed. 7. Compare conditional outcomes to pre-calculated results. 8. When the conditional finally passes, repeat for pre-calculated values of 9. M_2, N_2, and C_2. 10. Repeat steps 1-7 for all test cases listed above this table. VERIFY: ESAMS results match independent results. RESULT: Results did not match for the conditional check in test cases 5, 6, and 7, confirming error D1 found during desk-checking. Otherwise OK.
13-19	OBJECTIVE: Check groundline segment length through the facet. For this test the following site-target location coordinates are used: Site : (125.0, 125.0, 3.0) Target : (2625.0, 1625.0, 60.0) PROCEDURE: 1. Stop in subroutine FACET. 2. Stop on line 177. 3. Examine variable TMP and compare to the pre-calculated value. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-20	OBJECTIVE: Check coordinates of the next groundline-gridline intersection. For this test the following site-target location coordinates are used: Site : (125.0, 125.0, 3.0) Target : (2625.0, 1625.0, 60.0) PROCEDURE: 1. Stop in subroutine FACET. 2. Stop on line 153. 3. Examine variable INDX and compare to the pre-calculated value. 4. Repeat steps 2 and 3 for all facets. VERIFY:ESAMS values match independent calculations. RESULT: OK
13-21	OBJECTIVE: Check the gridplane difference deltas and the direction slopes. PROCEDURE: 1. Stop in subroutine FACIN. 2. Stop on line 133. 3. Examine variables DELX, DELY, COSB and SINB. 4. Compare to pre-calculated values. 5. Repeat steps 1-4 for each target location listed above this table. VERIFY:ESAMS values match independent calculations. RESULT: OK
13-22	OBJECTIVE: Check horizon limiting. Two test cases are considered to exercise both branches of the conditional statement in lines 142-148. These two cases position the site and target as follows: a. Site : (0.0, 0.0, 3.0) Target : (2500.0, 0.0, 60.0) b. Site : (0.0, 0.0, 3.0) Target : (7500.0, 0.0, 60.0) PROCEDURE: 1. Stop in subroutine FACIN. 2. Stop on line 142. 3. Step through lines of code:if running case a, then code should sequentially execute lines 142, 144, 148.if running case b, then code should sequentially execute lines 142, 146, 147, 148. 4. Stop on line 151. 5. Examine variables XMAX and YMAX and compare to pre-calculated values. VERIFY: 1. Correct lines are executed as noted in step 3. 2. ESAMS values match independent calculations in step 5. RESULT: OK

TABLE 2.13-8. Native Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-23	OBJECTIVE: Check MAX computations and the algebraic sign of the deltas. PROCEDURE: 1. Stop in subroutine FACIN. 2. Stop on line 175. 3. Examine variables XMAX, YMAX, KPT, LPT, SYNEX and SYNEY. 4. Compare to pre-calculated values. 5. Repeat steps 1-4 for each test case listed above this table. VERIFY: ESAMS values match independent calculations. RESULT:OK
13-24	OBJECTIVE: Check arrays of x-y intercepts and initial gridline points. PROCEDURE: 1. Stop in subroutine FACIN. 2. Stop on line 206. 3. Examine the contents of the array variables POINT(1,1), POINT(1,2), POINT(2,1), POINT(2,2), YNC(1,1), YNC(1,2), YNC(2,1), YNC(2,2). 4. Compare to the pre-calculated values. 5. Repeat steps 1-5 for each test case listed above this table. VERIFY: ESAMS values match independent calculations. RESULT: OK

Subroutines FSHAD and BSHAD provide forward and backward shadowing logic for spatially oriented terrain facets. Since ESAMS 2.6.2 only allows use of flat-earth terrain data, facet shadowing operations are not effective. No facets will be raised or tilted and therefore the height variables Z1 and Z2 passed into subroutines FSHAD and BSHAD from subroutine FACET will always be zero.

In FSHAD, T2 will always be less than T1 since Z1 = Z2 = 0.0 for all facets as the groundline progresses from the site to the target position. This implies that T2 will always be a minimum angle and the conditional branch in line 74 indicating a shadow situation will never be executed.

The remaining portion of the code computes the depression angles from the site to the facet edges at the groundline intersections and then computes the average depression angle between the two. This yields the depression angle to the center of the groundline segment passing through the facet. This value is stored in variable location POS(3,I) which was checked for accuracy after being passed to subroutine MULTIP into variable PSI1 (see software test case 13-3). To test the operation of subroutine FSHAD, each line of code, with the exception of the shadow flag setting in line 74, was executed using the DEBUG step mode.

As in FSHAD, the fact that Z1 = Z2 = 0.0 for all facets in subroutine BSHAD forces variable T1 to remain at a minimum value. No facet will be shadowed from the target and the conditional branch setting the shadow flag in line 96 will never be executed.

The remaining portion of subroutine BSHAD computes the depression angles from the target to the facet edges at the groundline intersections and then computes the average depression angle between the two. This quantity is stored in the variable location POS(4,I) which was checked for accuracy after being passed to subroutine MULTIP into variable PSI2 (see software test case 13-3). To test the operation of subroutine BSHAD, each line of code, with the exception of the shadow flag setting in line 96, was executed using the DEBUG step mode.

2.13.4.2 GRACE Mode Tests

The implementation of the GRACE design in Subroutine GRCMLT was software tested by independently calculating variable values and comparing the results to the computer-generated values. At the time of this verification effort, no terrain data was available for access through the Site Mask Generator (SMG) routines. Therefore, to perform the verification software tests described in Table 2.13-10, a test subroutine was written to replace the call to the data transfer subroutine SMGXFR on lines 163 and 164. The test subroutine generates a series of data values that would describe four illuminated facets along the first terrain data radial.

A target was positioned over this radial at

$$(x_T, y_T, z_T) = (20.0, 2000.0, 60.0)$$

Target velocity was set at 200 m/s and the flight path was directed toward the site at a heading of 270˚.

The lines of code that implement the radar range equation were executed and examined for reasonable output (direction, magnitude), but were not checked for accuracy since they heavily depend on antenna gain computations performed outside the multipath functional element. The coded implementations of these equations were examined during the desk-check stage and found to be correctly implemented.

TABLE 2.13-9. GRACE Mode Multipath Test Cases.

Test Case ID	Test Case Description
13-25	OBJECTIVE: Check target bearing and elevation angle computations. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 201. 3. Examine variables XTS, YTS, ZTS, TARBNG and TARELV. 4. Compare to pre-calculated values. VERIFY: ESAMS values match independent calculations. RESULT: OK

TABLE 2.13-9. GRACE Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-26	OBJECTIVE: Check radial number calculations and data transfer. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 207. 3. Examine variables DELAZ, IAZTAR and NFACET. 4. Compare to pre-calculated values. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-27	OBJECTIVE: Check antenna gain and power computations PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 229. 3. Compare values of XTHAT, YTHAT, and ZTHAT to the pre-calculated values. 4. Examine gain values TSUM, TAZ, and TEL for reasonableness. 5. Examine the power gain factor POWERK for reasonableness. VERIFY: 1. ESAMS values match independent calculations in step 3. 2. ESAMS values in steps 4 and 5 are reasonable. RESULT: OK
13-28	OBJECTIVE: Check grazing angle calculations for each facet. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 257. 3. Examine variables THETA2 and THET1. 4. Compare with pre-calculated values. 5. Repeat steps 2-4 for all facets. VERIFY: ESAMS values match independent calculations. RESULT:OK
13-29	OBJECTIVE: Check effective radial length and scattering area of the facet. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 259. 3. Examine variables DSUBE and ASUBE. 4. Compare to the pre-calculated values. 5. Repeat steps 2-4 for all facet. VERIFY: ESAMS values match independent calculations. RESULT: OK

TABLE 2.13-9. GRACE Mode Multipath Test Cases. (Contd.)

Test Case ID	**Test Case Description**
13-30	OBJECTIVE: Check specular reflection coefficient computation. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 271. 3. Examine variable GANSPC and compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: Compared values for GANSPC were not an exact match. This is due to the fact that the sin(x)/x function is rapidly changing in some intervals, causing large output variations for small input changes. The gain factor does appear to be reasonable, however, considering the change in magnitude over the three facets.
13-31	OBJECTIVE: Check the power gain of the diffuse and specular components. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 277. 3. Examine variable SRC and compare with pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-32	OBJECTIVE: Check target-facet geometry computations PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 308. 3. Examine variables XFACET, YFACET and ZFACET. Compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-33	OBJECTIVE: Check target doppler computations PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 314. 3. Examine variable DOPPLR and compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK

TABLE 2.13-9. GRACE Mode Multipath Test Cases. (Contd.)

Test Case ID	Test Case Description
13-34	OBJECTIVE: Check antenna gain in the direction of the facets and target RCS computations. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 327. 3. Examine values of FSIGD, FSUM, DIF1 and DIF2 for reasonableness. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-35	OBJECTIVE: Check multipath phase delay calculations. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 330. 3. Examine variable PHDLA and compare to pre-calculated values. 4. Repeat steps 2 and 3 for each facet. VERIFY: ESAMS values match independent calculations. RESULT: OK
13-36	OBJECTIVE: Check sum and difference channel voltages for each facet contribution. PROCEDURE: 1. Stop in subroutine GRCMLT. 2. Stop on line 350. 3. Examine variables SUML1, DF1ML and DF2ML. Compare to pre-calculated values. 4. Repeat steps 2 and 3 for all facets. VERIFY: ESAMS values match independent calculations. RESULT: OK

2.13.5 Conclusions and Recommendations

2.13.5.1 Code Discrepancies

Several discrepancies were found in the native mode implementation of multipath. The most significant problem found is that multipath effects are calculated and included in signal processing when, in fact, no multipath is possible because the first Fresnel zone does not intersect the ground. In addition, the approximation used in ESAMS for the length of this first Fresnel zone differed by as much as 2000 meters from exact calculations.

Errors were also found in the facet geometry computations; the determination of whether the next ground line intersection is with a vertical or a horizontal grid line and the check to see if the ground line has reached the last facet (under the target or at the horizon) are both incorrect. Computation of the facet azimuth and elevation angles use the wrong reference frame.

Finally, the native mode implementation uses small angle approximations without checking for the appropriateness of these models; this may cause problems at the facets nearest the site and nearest the target.

No code discrepancies were found in the GRACE mode implementation.

2.13.5.2 Code Quality and Internal Documentation

Code quality in the native mode implementation is generally good; however, Subroutine FACET has mixed mode arithmetic and a variable in a common block that is used only locally. In GRACE mode, the variable ZTRI resulting from a Ricean draw is not used computationally; this draw may be unnecessary.

Internal documentation is generally good for native mode, although some portions of subroutine headers were blank and some internal comments apparently were written by someone who wasn't sure about the rationale for the coding logic. In addition, some comments mentioned numbered references that are not identified in the code, and there is no comment to document the fact that the vegetation scattering coefficient is assumed to be unity.

2.13.5.3 External Documentation

External documentation was not evaluated for this FE in ESAMS 2.6.2. The ESAMS 2.5 manuals were not updated for this model version.

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